Preliminary considerations about the assessment and visualisation of the quality on geometric corrections of satellite imagery depending on the number of ground control points

Gerard Moré[1,2], Xavier Pons[2]

[1] Centre for Ecological Research and Forestry Applications (CREAF), C-Building, Universitat Autònoma de Barcelona. 08193 Cerdanyola del Vallès. Spain
G.More@creaf.uab.cat
[2] Department of Geography, Universitat Autònoma de Barcelona. 08193 Cerdanyola del Vallès. Spain
Xavier.Pons@uab.cat

Abstract

Georeferencing satellite images is an essential procedure to carry out most remote sensing applications. The quality of this process will affect all the ulterior procedures and products. Independent test ground control points (GCPs) are required to assess the quality of the correction. However, a representative number is hardly obtained when they are manually located. This work studies the effect of the number of GCPs in the geometric correction quality when they are manually located. The methodology has been applied to Landsat TM images in a region with complex relief (heights ranging from 0 to 3000+ m). The work presents a spatial representation of the error and discusses its role in the visualisation of the quality. Moreover, we critically discuss the usage of indicators as the RMS error without considering the number of GCPs or the method used in their placement in the realistic assessment of the geometric quality of the imagery. Indeed, it is shown that, for the studied scenes, a minimum of 25 GCPs is needed to achieve a test RMS smaller than a pixel and that not using independent GCPs leads to unrealistic quality indicators. Moreover, manual placement of GCPs gives clearly worst results than automatic procedures.

Keywords: Landsat, RMS, geometric accuracy, number of Ground Control Points.

1 Introduction

The huge amount of currently available remote sensing information leads to an increasing interest in the data quality. An example of this interest is the EU 7th framework programme project “GeoViQua: Quality aware Visualisation for the Global Earth Observation System of Systems” (GeoViQua, 2010). The aim of this project is to scientifically define data quality indicators and quality-enabled search and visualisation tools to be applied to the clearinghouses and geoportals provided by the GEOSS (Global Earth Observation System of Systems) Common Infrastructure.

Remote sensing data quality implies several aspects about data, such as geometry, radiometry, uncertainty of the models applied to the data, propagation of errors when combining several layers, etc. Geometry is one of the most relevant as it leads to important implications when combining data from different dates or from different sources (for instance, images acquired by different sensors or combining satellite images with other geographic datasets or with field information).

Geometric correction with GCPs consists on three phases (Chuvieco, 2010): a) location of homologous GCPs between the image to be corrected and a reference image or map; b) fitting of the model to transform the reference coordinate system to the image to be corrected coordinate system; c) resampling the pixels in the corrected space by transferring the original values (on the image to be corrected) to the new position according to the model previously set.

GCPs location is a highly relevant step because the quality of the correction depends on the precision of their location and on their distribution over the scene. The optimal number of GCPs will depend on the complexity of the scene and, a part that the minimum number depends on the model to be used, there is no consensus about a general recommendation. For instance, Berstein (1978) recommends a number between 14 and 20 GCPs to correct a Landsat MSS image while Davison (1984) recommends a number between 100 and 120 GCPs to correct a Landsat TM image.

The quality of the geometric correction can only be clearly determined by an independent test. However, it is possible to study how the number of GCPs impacts on the quality of the geometric correction in order to give a general figure of the quality when an independent test is not available for an image as well as to assess the reliability of the usage of a quality indicator derived from the GCPs used to fit the model.

The RMS (root mean square) error is a very usual indicator of the geometric quality of the correction, but in many cases it is not reported how this figure has been estimated: How many points? How were they collected? Were they independent or the RMS was computed from the same set used to fit the model? Moreover, a spatialized indicator of the quality can be very useful to know which parts of the scenes are more reliable and which parts contain more geometric errors, so contributing to the visual assessment and understanding of the spatial quality.

The objective of this work is twofold: 1/ To evaluate how the quality of the geometric correction varies depending on the number of GCPs used, on the GCPs placement methodology or on their role in the model fitting. 2/ To take a glance at the spatial representation of the quality of such geometric corrections.

2 Study zone and materials

The study zone is over the Landsat scenes 197-031 and 198-031 according to the WRS-2 (Worldwide Reference System). Both scenes cover most of the territory of Catalonia, on the north-east of the Iberian Peninsula. The study zone presents zones with heavy relief (from the sea level to heights higher than 3000 m in the Pyrenees) besides of zones of moderate topography.

A Landsat 5 TM image for each scene has been used: 9 May 2007 for 198-031 and 18 May 2007 for 197-031. These images belong to an annual Eurimage subscription of Landsat images and have been selected for their cloud-free conditions. Two set of GCPs have been used for each image: a set of manually GCPs (close to 30 GCPs) and a set of automatically GCPs (with more than 230 GCPs) (see Table 1).

Table 1. Acquisition date and number of GCPs used for each scene.

Scene	Acquisition date (*dd/mm/yyyy*)	Number of GCPs manually set	Number of GCPs automatically set
197-031	18/05/2007	33	243
198-031	09/05/2007	26	238

The procedure to obtain these GCPs is explained in the following section. The Digital Elevation Model was downloaded from the Institut Cartogràfic de Catalunya (15 m of spatial resolution). Areas outside Catalonia were filled with the ASTER Digital Elevation Model data.

3 Methodology

3.1 Geometric correction model

Landsat images are commonly georeferenced by fitting a polynomial according to a set of GCPs. Palà & Pons (1995) has been successfully used for long series of Landsat imagery (since 1972 to nowadays) and also in the present work. This methodology consists on a first polynomial function that takes into account the relief displacements.

GCPs can be set manually by a human operator or they can be set by an automatic methodology. The automatic ground control point searching methodology proposed in Pons *et al.* (2010) consists on finding homologous points between a satellite image and an orthophotomap through correlation analysis. One important feature of this methodology is that the distribution of the GCPs is not according to the presence of identifiable features in the image but to an optimal distribution of GCPs according to the polynomial with Z functions. Consequently, the distribution of the automatic GCPs covers the complete range of the X, Y and Z of the scene.

According to an experience of more than ten years (and hundredths of corrected images) the number of GCPs per scene that can be manually successfully set is limited to about 30 and to regions clearly identifiable by the human eye (even if the operator has a large expertise in this task). If more GCPs are desired, the operator has to deal with regions harder to identify and with an increasing uncertainty in the location of the GCPs and, consequently, in a worse fitting of the polynomials. A computerized method can successfully deal with regions hardly identifiable by a human, so the distribution of GCPs is not limited to recognizable zones but it can be set according to the proposed model.

Our hypothesis is that the lower the number of used GCPs, the lower the quality of the correction. Given that the number of manually identified GCPs is limited, the dropout of a point will cause a worse distribution of GCPs on the X, Y and Z space.

3.2 The influence of the number of GCPs

In this work a set of manually identified GCPs is used to fit the model and a set of automatically GCPs is used to test the equations fitting. A subset of the manually identified GCPs has been used in order to answer the question about how the number of GCPs influences the quality of the geometric correction.

The number of possible combinations is extremely large and, for this work, 30 random combinations have been selected for each number of GCPs used (30 random combinations using 30 GCPs, 30 random combinations using 25 GCPs, and so on). For scene 198-031, with 26 original GCPs, there was no possibility to select 30 GCPs as they were only 26 (and not 30) possible combinations using 25 GCPs.

3.3 Quality assessment and error visualisation

The global quality of the geometric correction is numerically assessed by the RMS error. A reasonably high number of test GCPs allows spatializing the errors detected during the model testing stage. In this work a preliminary vector error visualisation that consists on representing the error vector of each test ground control point is presented. As the errors are usually smaller than a pixel, the length of this vector was exaggerated by a factor x100 in order to be conveniently represented at general scales. In this paper only some cases of the 197-031 will be visualized because of the lack of space, but the results with the other frame are similar.

4 Results

Figure 1 shows that, as expected, the mean test RMS increases when the number of GCPs decreases for both scenes. Variability in results also increases when using a lower number of GCPs. It can be explained by the fact that with a lower number of GCPs the distribution of X, Y, Z is hardly covered.

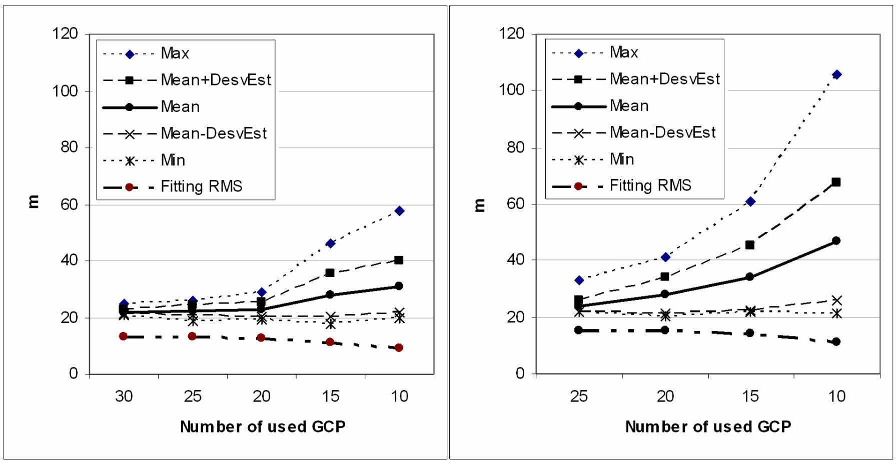

Figure 1. RMS statistics (Maximum, Mean, Minimum, etc) obtained from 200+ independent GCPs for the different combinations of GCPs for scene 197-031 (on the left) and for scene 198-031 (on the right) (upper lines) compared to the RMS computed from the fitting GCPs themselves (in this case the mean fitting is plotted as a thick dotted line).

If GCPs are manually located, the estimated quality obtained by the fitting RMS (without an independent set of GCPs) is excessively optimistic: For the images evaluated in this work, the RMS estimated from the fitting is about 14 m when using all the available manual GCPs. However, the RMS obtained by an independent test based on hundredths of GCPs is about 23 m. Moreover, when the number of GCPs is decreasing, the tendency of the RMS computed from the GCPs used to fit the model is opposite to that of the test RMS: The first one is biased in the sense that it informs that quality increases when using less GCPs, which is wrong.

If the quality of the correction is assessed by an abundant independent set of GCPs, it is found that a minimum number of 25 GCPs must be used to achieve a RMS similar to the maximum obtained using all the GCPs manually placed.

A number higher than 30-35 GCPs is hardly achieved when they are manually located. RMS values can significantly improved when an automatic algorithm is used to identify hundredths of fitting GCPs. It seems that, for an image with heavy relief (0-3000+ m), the best possible RMS with manually located GCPs is about 22.9 m while with an automatic procedure the mean RMS is about 15.5 m (Pons *et al.*, 2010).

Figure 2 shows the spatialized error representation as oriented line vectors. When using all the available GCPs (left), all error vectors have a reasonably short length and there is not an identifiable pattern in the orientation of the errors. When using a selection of the original GCPs (right), error vectors increase in length in zones where GCPs were missed (for instance, at the centre of the scene). No differences were detected on the direction of the errors, although it is a preliminary study.

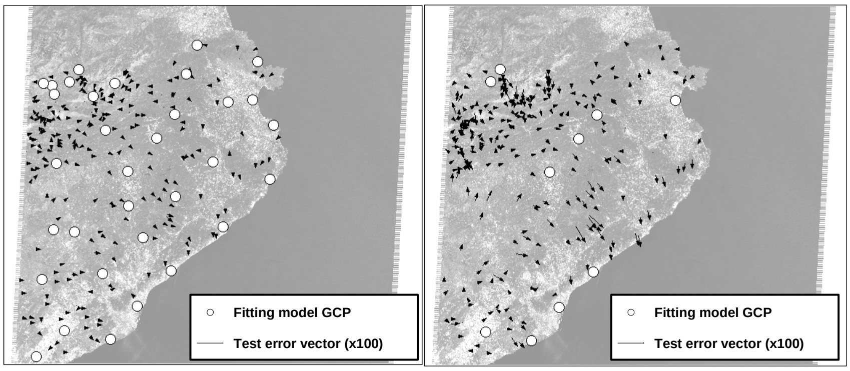

Figure 2. Test error vectors for scene 197-031. Vector lengths are exaggerated by a x100 factor. No graphic scale is plotted because the image is not georeferenced. Left: correction with all the available GCPs for this scene (test RMS=22.9 m). Right: correction with a selection of 10 GCPs (test RMS=33.2 m).

The error vector representation allows visualising the magnitude of the errors, their spatial distribution and the eventual existence of patterns in their directions.

Other forms of quality visualisation, as continuous layers obtained by interpolation of the error magnitude and direction, will be studied in future work.

5 Conclusions

This work reveals the importance of knowing two additional parameters besides the RMS error when assessing the geometric accuracy. These two parameters are the number of used GCPs used to fit the model and if the RMS has been computed based on the fitting GCPs set or based on an independent set of GCPs. The fitting GCPs RMS is biased, giving a lower (optimistic) RMS than the RMS obtained by an independent test. This bias increases when the number of fitting GCPs decreases.

If GCPs are manually located, a minimum of 25 GCPs are recommended to obtain an acceptable quality in the correction. Nevertheless, given that the manually location of GCPs is limited to 30-35 GCPs, the quality of the geometric correction is also limited. Indeed, using an automatic procedure to find hundredths of GCPs can improve significantly the results (22.9 m *versus* 15.5 m of RMS error).

Vector-based visualisation allows to easily detect points with high error magnitude and direction patterns.

Acknowledgments

Parts of this study will be used as pilot case in the FP7 European project "QUAlity aware VIsualisation for the Global Earth Observation System of Systems (GeoViQua)" (Ref. 265178). Xavier Pons is recipient of an ICREA Acadèmia Excellence in Research grant (2011-2015). This work has been partially supported by the Catalan Government grant GRUMETS 2009 SGR 1511.

References

Bernstein, R. (1978), “Digital image processing of Earth observation sensor data”. *In*: Bernstein, R. (ed.). *Digital Image Processing for Remote Sensing*, New York, IEEE Press: pp. 55-72.

Chuvieco, E. (2010), *Teledetección ambiental. La observación de la Tierra desde el espacio*, Ariel, Barcelona, Spain, 590p.

Davison, G. J. (1984), “Ground control pointing and geometric transformation of satellite imagery”. *Remote Sensing Workshop on Terrestrial Positioning and Geometric Correction of Imagery*, Nottingham, Department of Geography, University of Nottingham: 45-59.

GeoViQua (2010) GeoViqua project description. In Internet at http://www.geoviqua.org/ (as of March 18 2011).

Palà, V., X. Pons (1995), “Incorporation of relief in polynomial-based geometric corrections”. *Photogrammetric Engineering and Remote Sensing*, Vol. 61: 935-944.

Pons, X., Moré, G., Pesquer, L. (2010), “Automatic matching of Landsat image series to high resolution orthorectified imagery”. *In*: Lacoste-Francis (ed.) *Proceedings of THE 2010 ESA Living Planet Symposium*, ESA Communications, Noordwijk, Holanda (CD-ROM, ISBN: 978-92-9221-250-6).